

Large Scale Traveling Ionospheric Disturbances Observed using HamSCI Amateur Radio, SuperDARN, GNSS TEC, and Ionosondes.

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⁶Virginia Tech

Traveling Ionospheric Disturbances

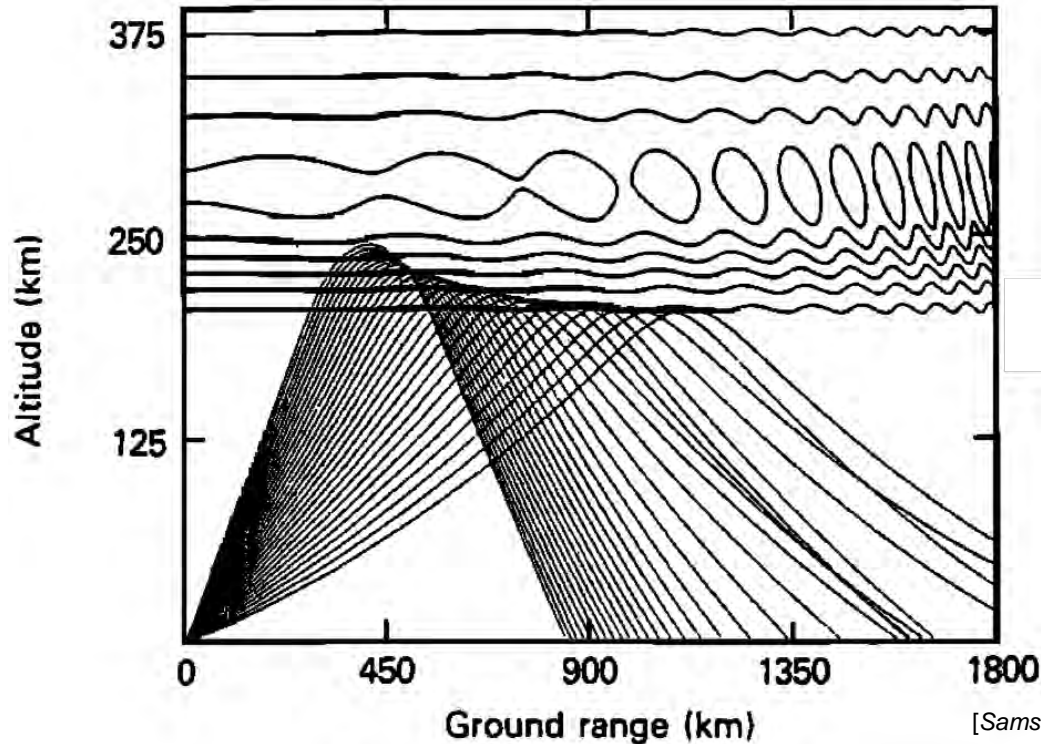
- **TIDs are Quasi-periodic Variations of F Region Electron Density**
- **Medium Scale (MSTID)**
 - $T \approx 15 - 60$ min
 - $v_H \approx 100 - 250$ m/s
 - $\lambda_H \approx$ Several Hundred km (< 1000 km)
 - Often Meteorological Sources
- **Large Scale (LSTID)**
 - $\lambda_h > 1000$ km
 - $30 < T [\text{min}] < 180$
 - Often Auroral Electrojet Enhancement, Particle Precipitation
- **Often associated with Atmospheric Gravity Waves**

[Francis, 1975; Hunsucker 1982; Ogawa et al., 1967; Ding et al., 2012; Frissell et al., 2014;

2016]

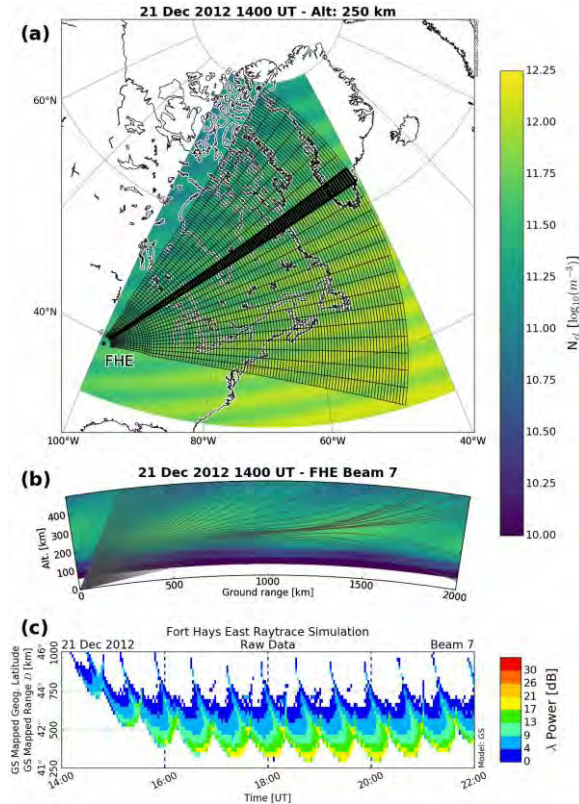
Traveling Ionospheric Disturbances

MSTIDs are a type of HF Fading



[Samson et al., 1990]

Traveling Ionospheric Disturbances



Ray trace simulation illustrating how SuperDARN HF radars observe MSTIDs.

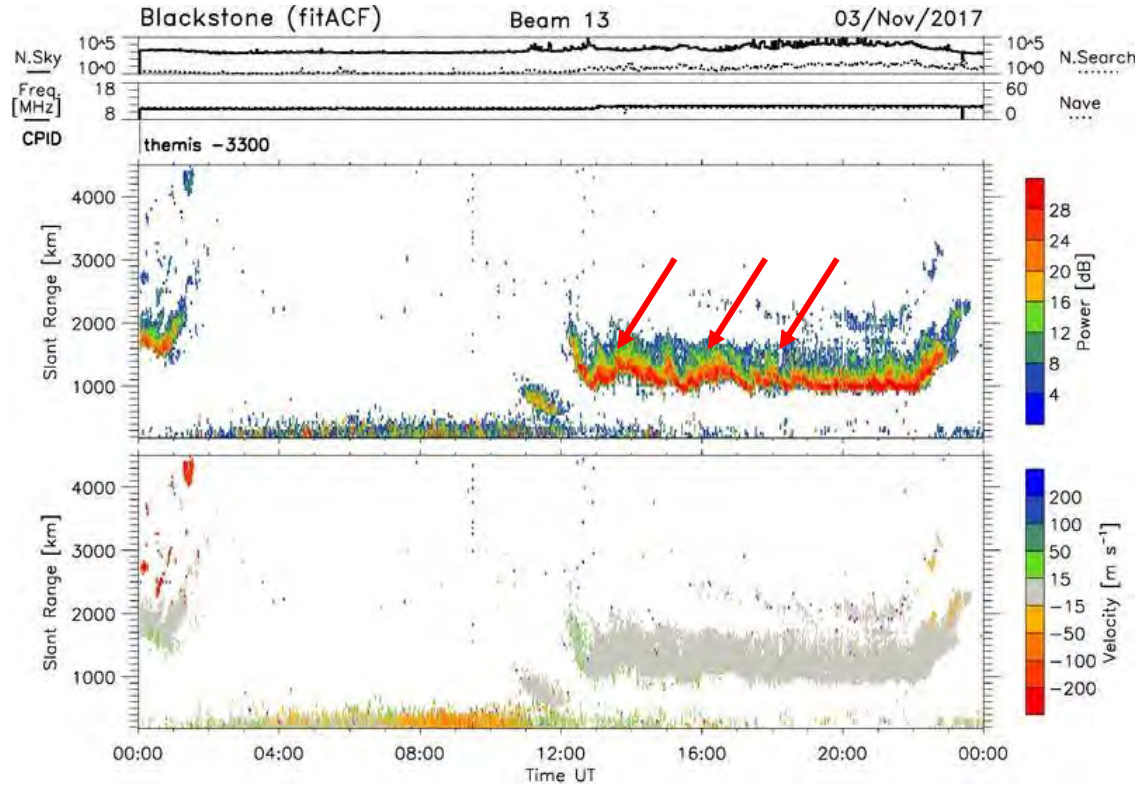
- (a) Fort Hays East (FHE) radar field of view superimposed on a 250 km altitude cut of a perturbed IRI. FHE Beam 7 is outlined in bold.
- (b) Vertical profile of 14.5 MHz ray trace along FHE Beam 7. Background colors represent perturbed IRI electron densities. The areas where rays reach the ground are potential sources of backscatter.
- (c) Simulated FHE Beam 7 radar data, color coded by radar backscatter power strength. Periodic, slanted traces with negative slopes are the signatures of MSTIDs moving toward the radar.

[\[Frissell et al., 2016\]](#)

Data Sources

- **Ham Radio**
 - Reverse Beacon Network
 - Weak Signal Propagation Reporting Network (WSPRNet)
 - QRZ.com
- **SuperDARN**
- **Madrigal GPS Total Electron Content (TEC)**
- **NASA OMNI Data**
- **Ionosonde foF2 Data**

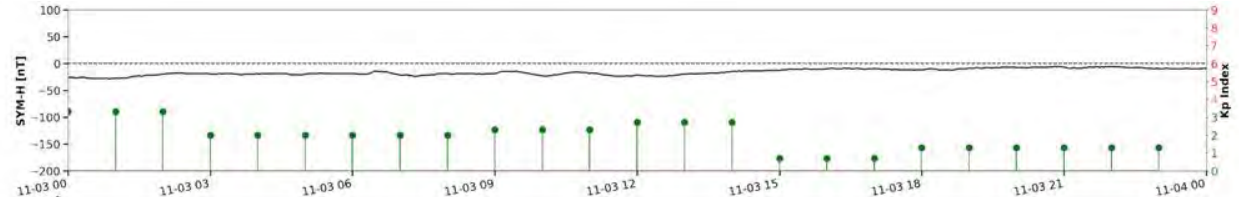
HamSCI
<http://hamsci.org>



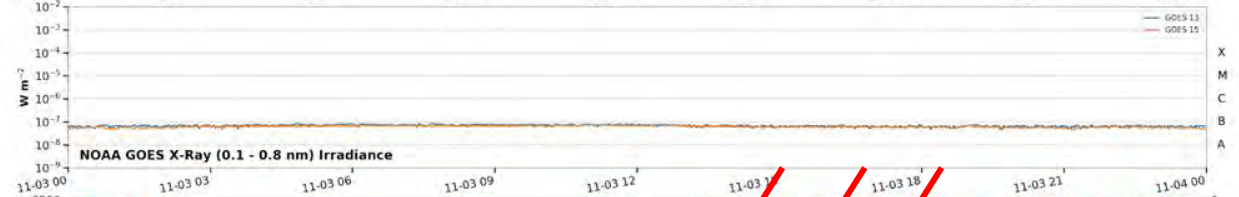
Ham Radio TIDs

N Spots = 157559
RBN: 29%
WSPRNet: 71%

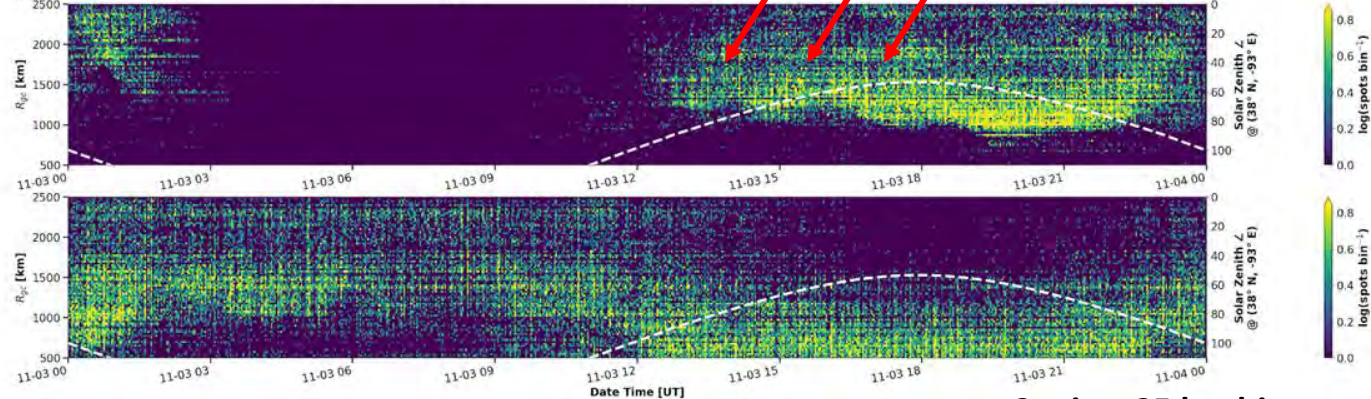
(a)
 K_p
Index



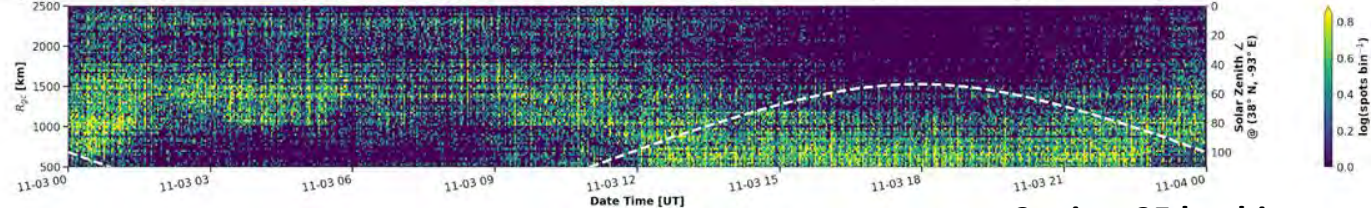
(b)
GOES
X-Ray



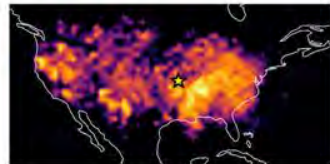
(c)
14 MHz



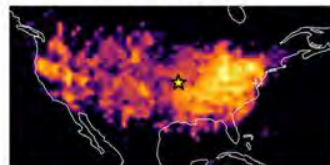
(d)
7 MHz



2 min x 25 km bins

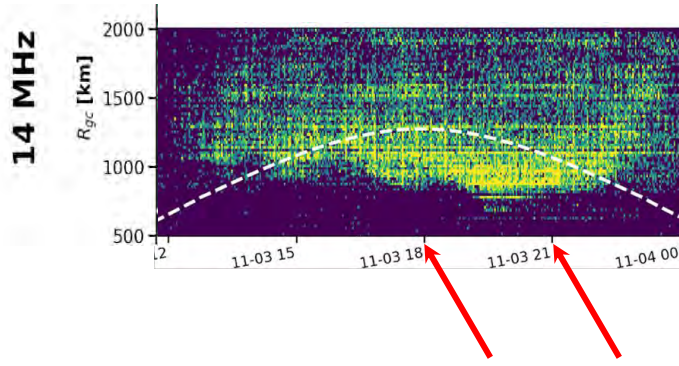


Radio Spots (N = 61561)

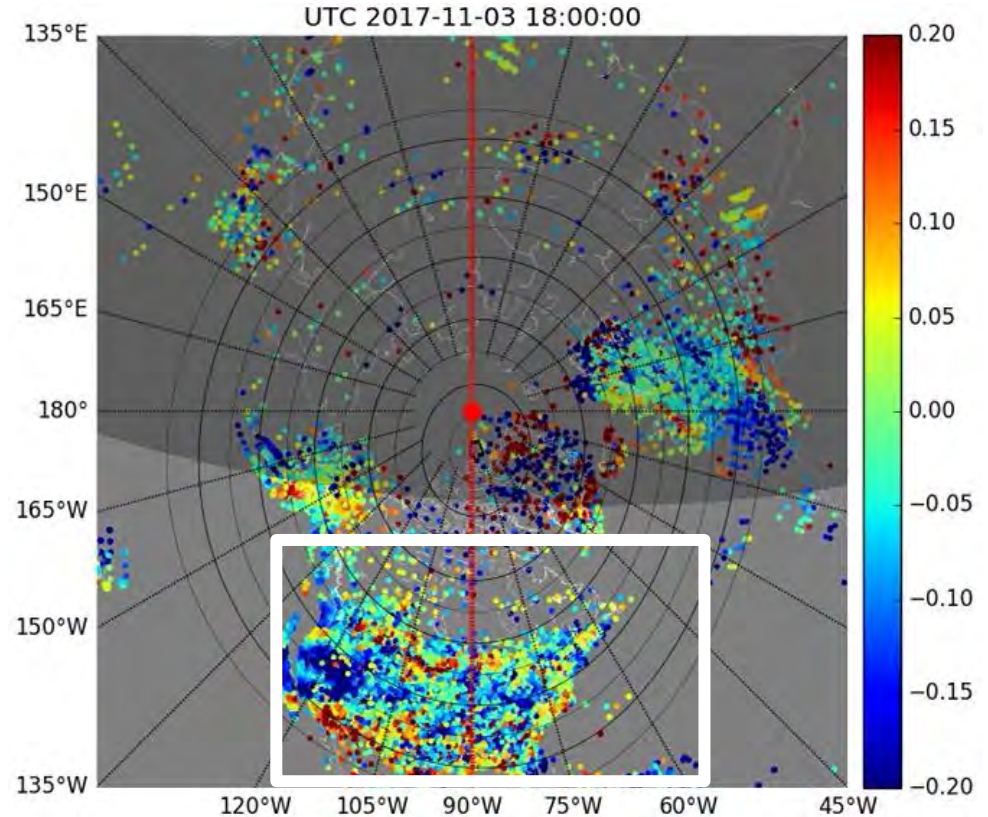


Radio Spots (N = 95998)

GNSS TEC Comparison 18:00 - 21:00

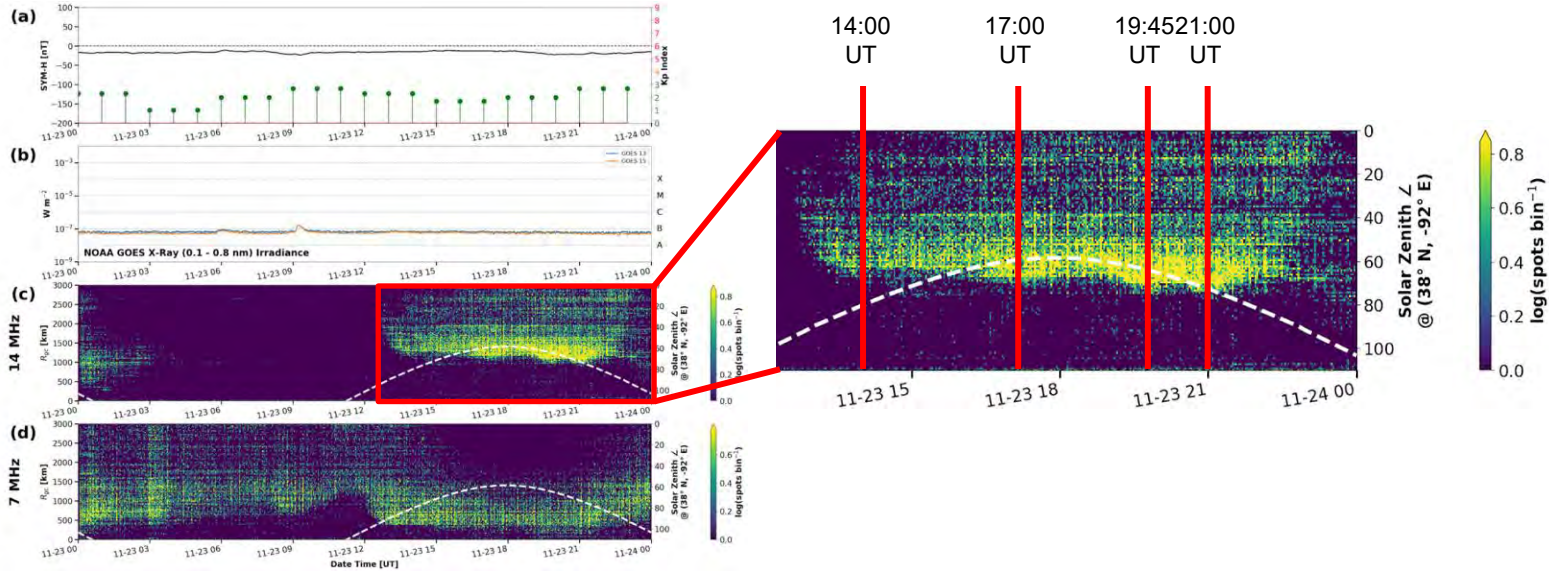
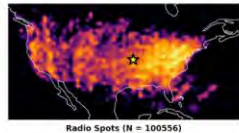
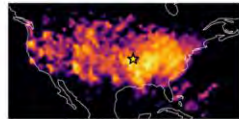


- Radio range is shortest when TEC is red (higher TEC)
- Higher electron densities → More HF refraction, communication range decreases



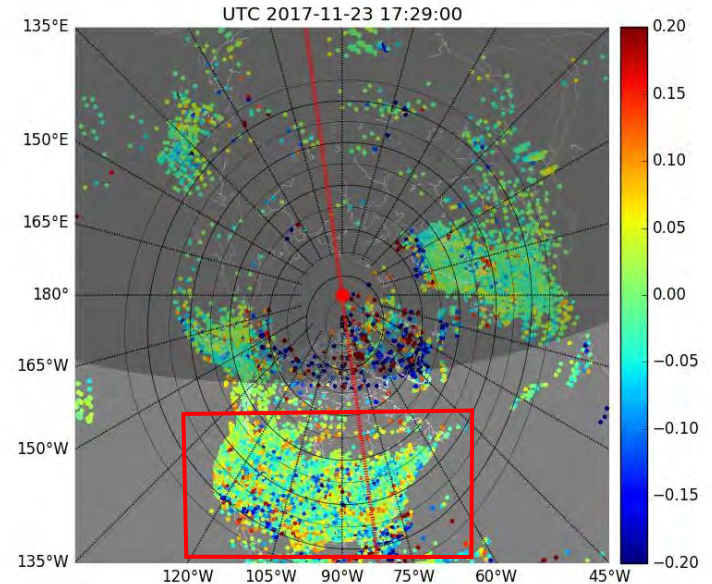
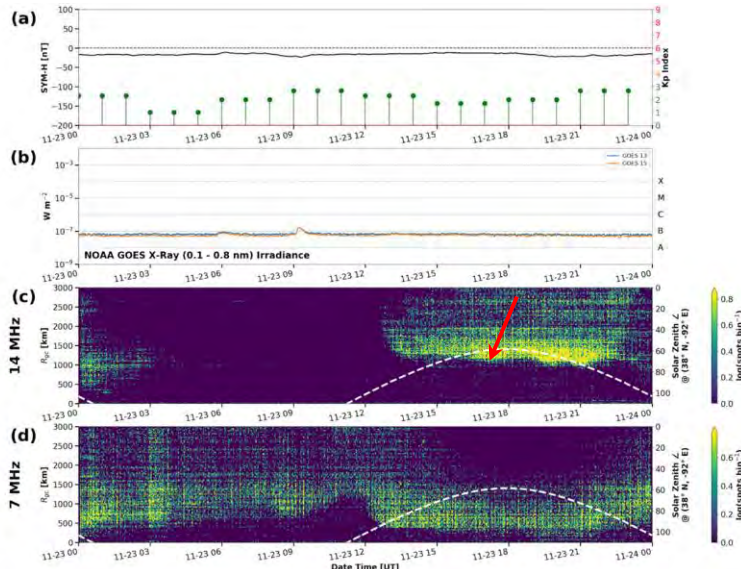
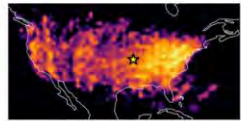
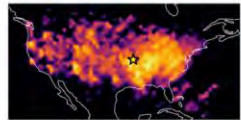
November 3, 2017 US Ham Radio TID

23 Nov 2017-
24 Nov 2017
Ham Radio Networks
N Spots = 175674
RBN: 38%
WSPRNet: 62%



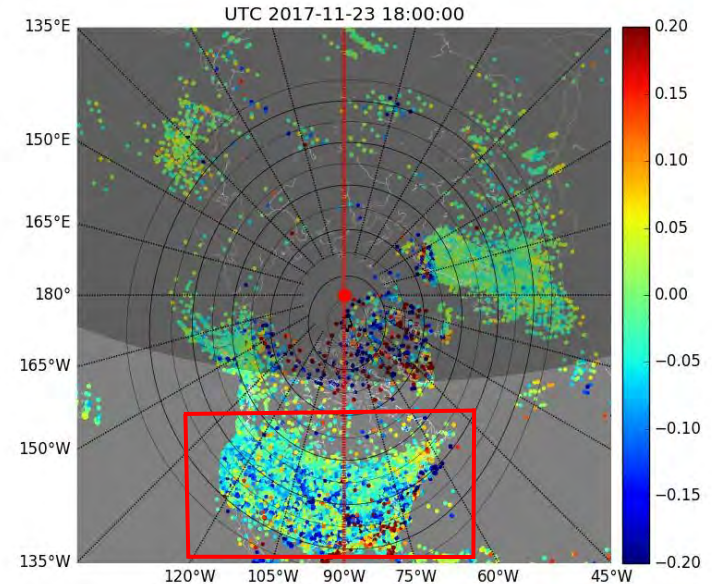
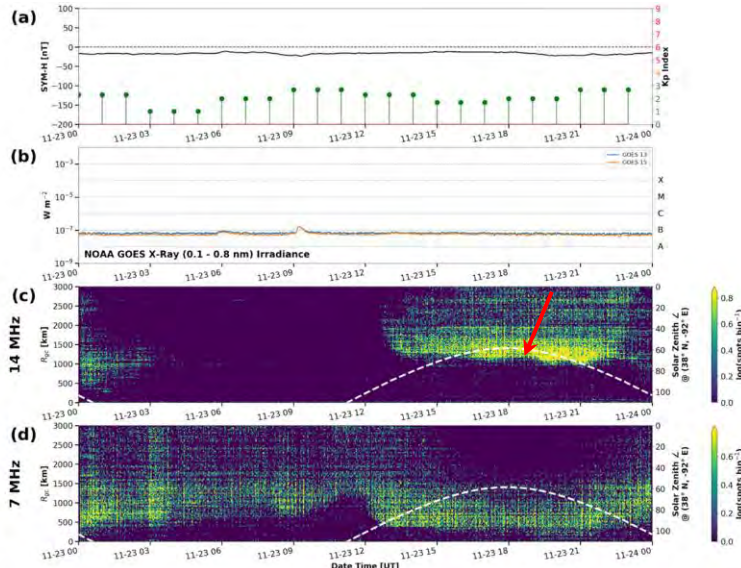
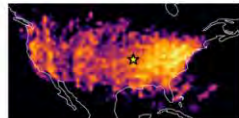
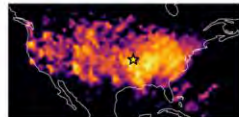
Nov 23, 2017 GNSS TEC Comparison

23 Nov 2017-
24 Nov 2017
Ham Radio Networks
N Spots = 175674
RBN: 38%
WSPRNet: 62%



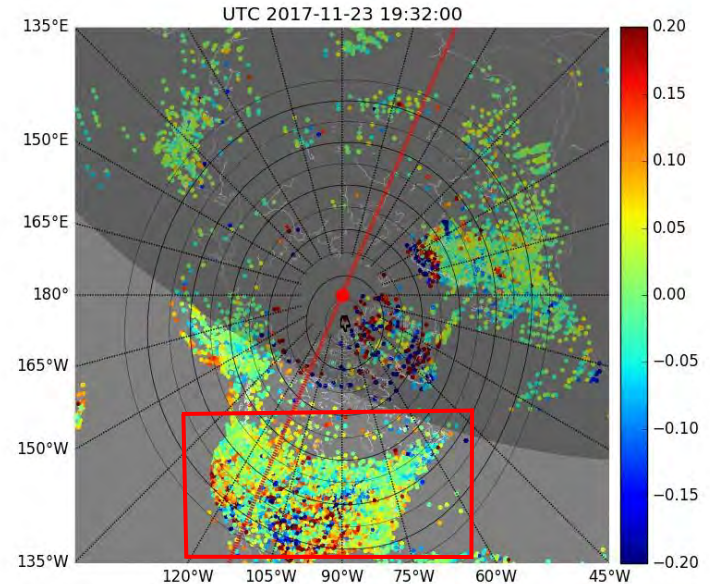
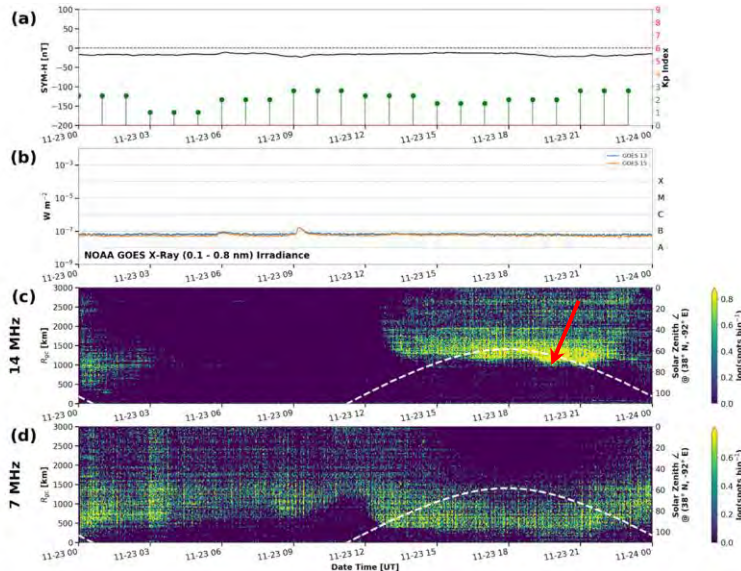
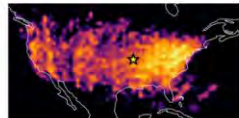
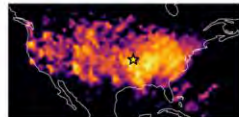
Nov 23, 2017 GNSS TEC Comparison

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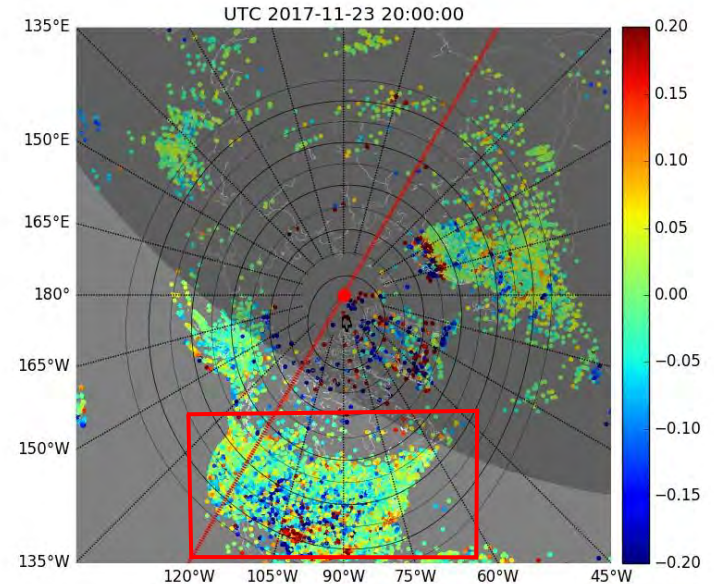
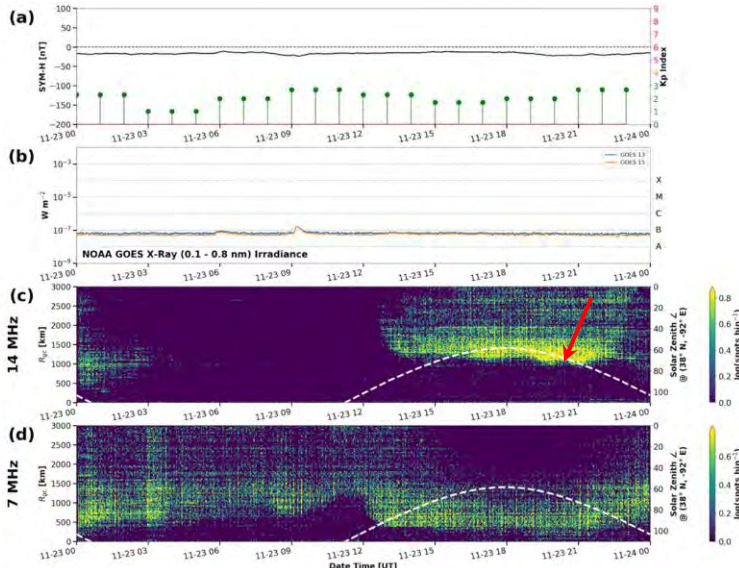
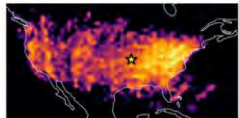
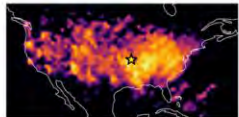
Nov 23, 2017 GNSS TEC Comparison

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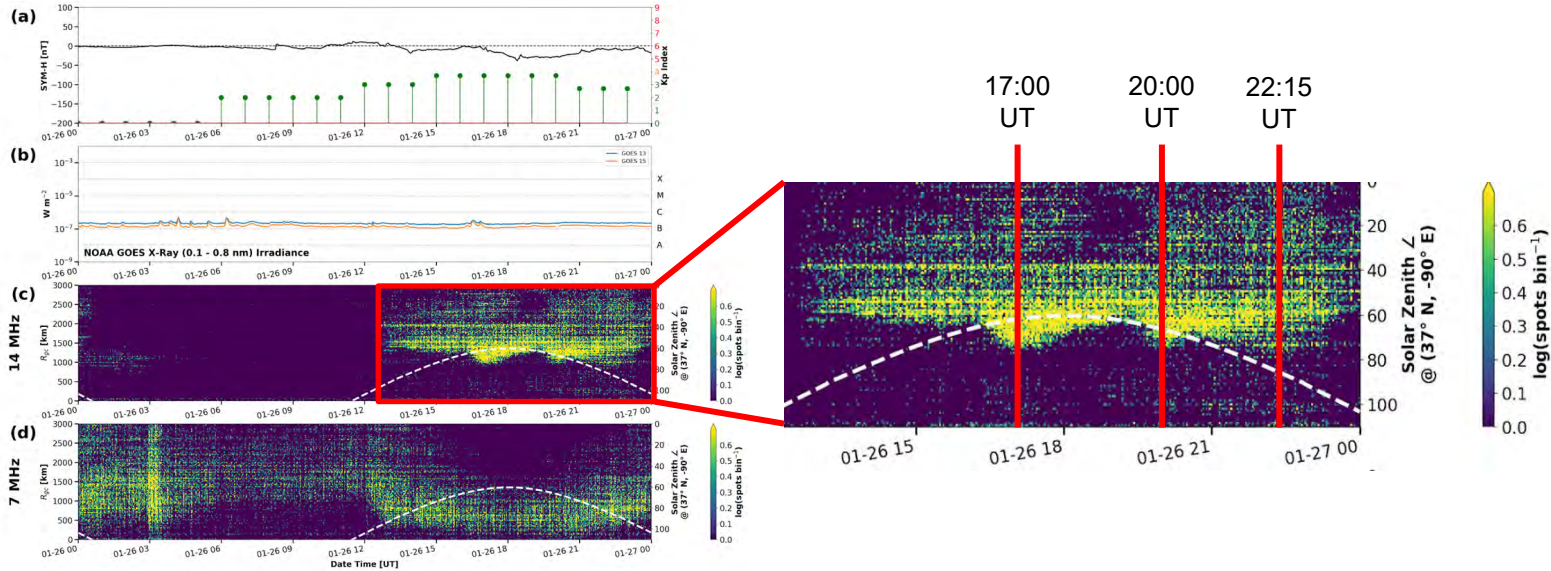
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24 Nov 2017
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RBN: 38%
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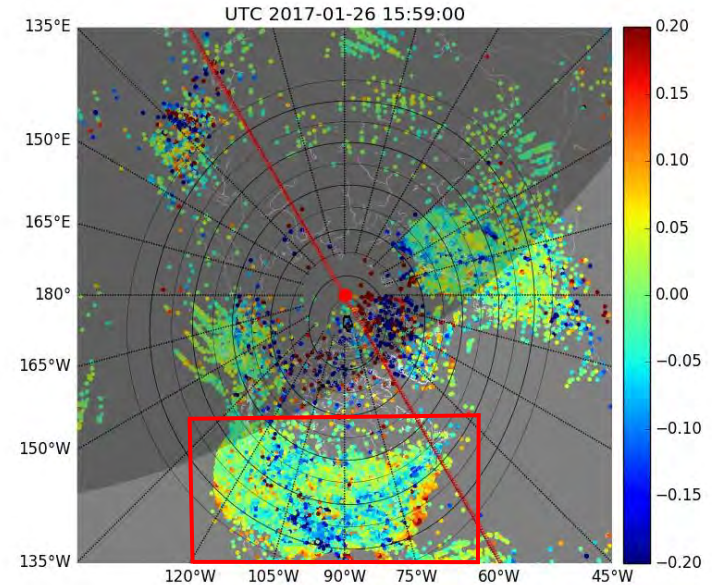
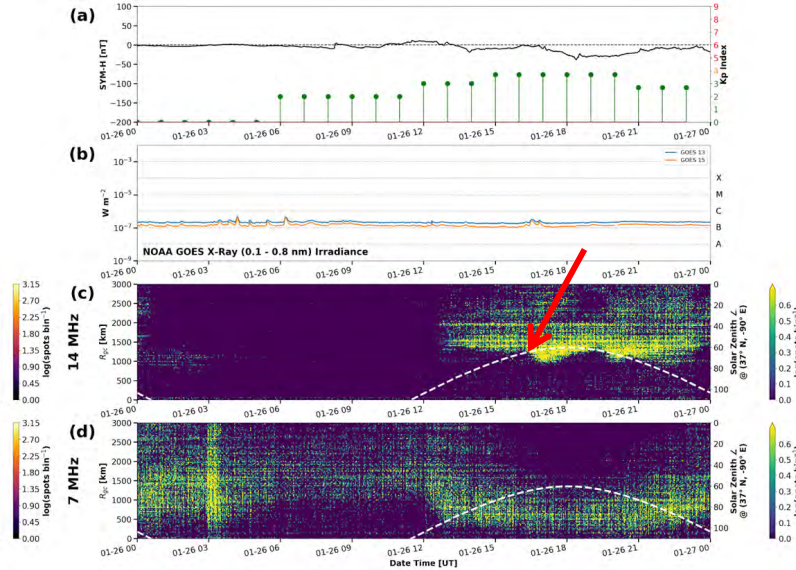
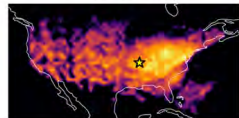
January 26, 2017 US Ham Radio TID

26 Jan 2017-
27 Jan 2017
Ham Radio Networks
N Spots = 151871
RBN: 48%
WSPRNet: 52%



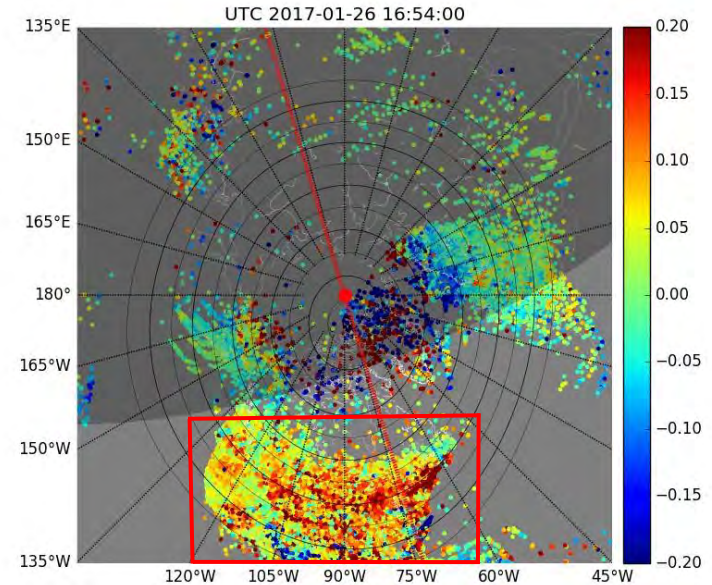
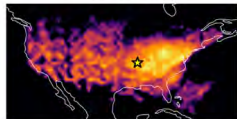
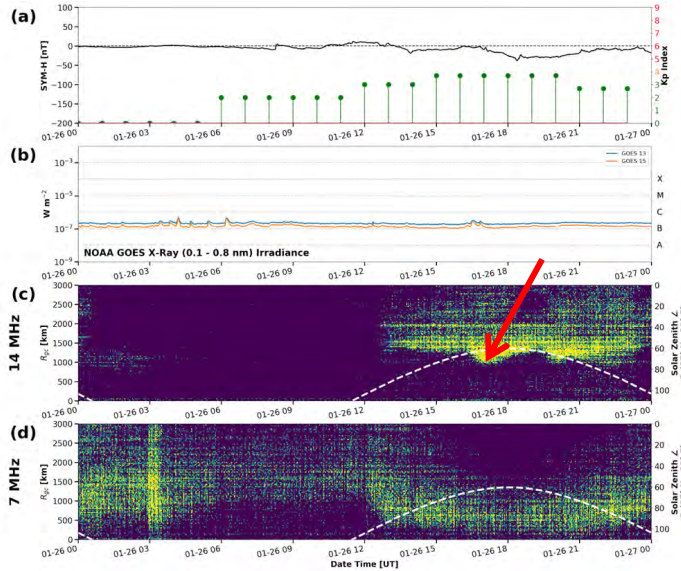
Jan 26, 2017 GNSS TEC Comparison

26 Jan 2017-
27 Jan 2017
Ham Radio Networks
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WSPRNet: 52%



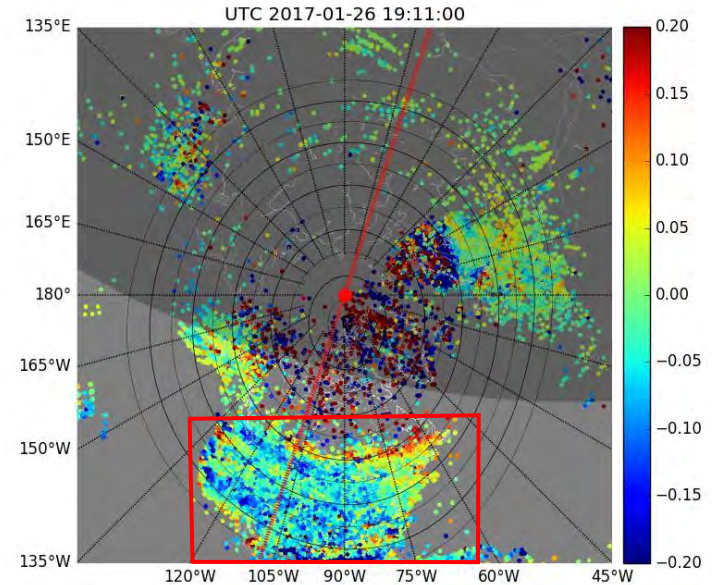
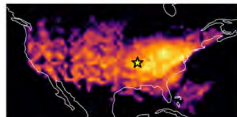
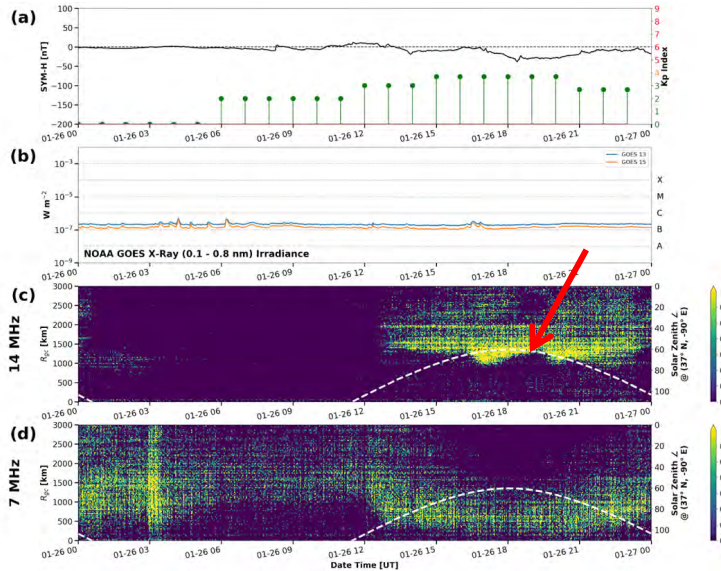
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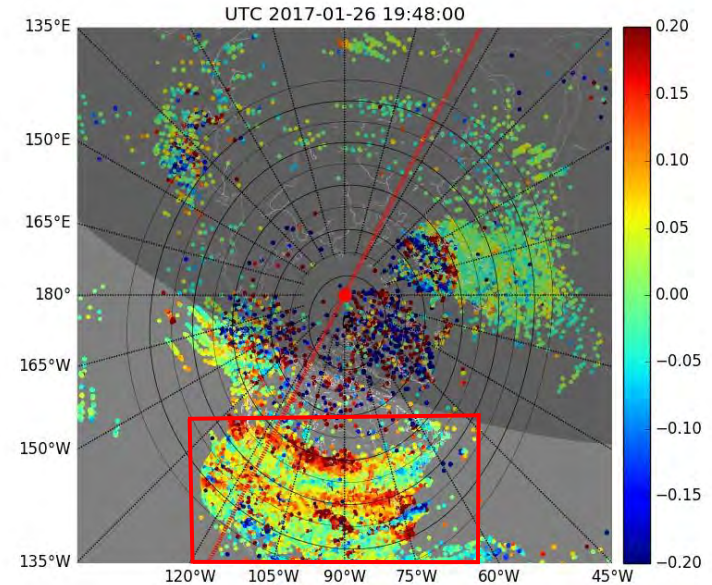
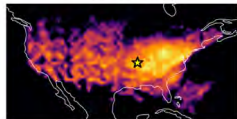
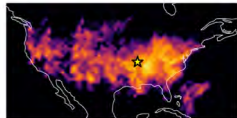
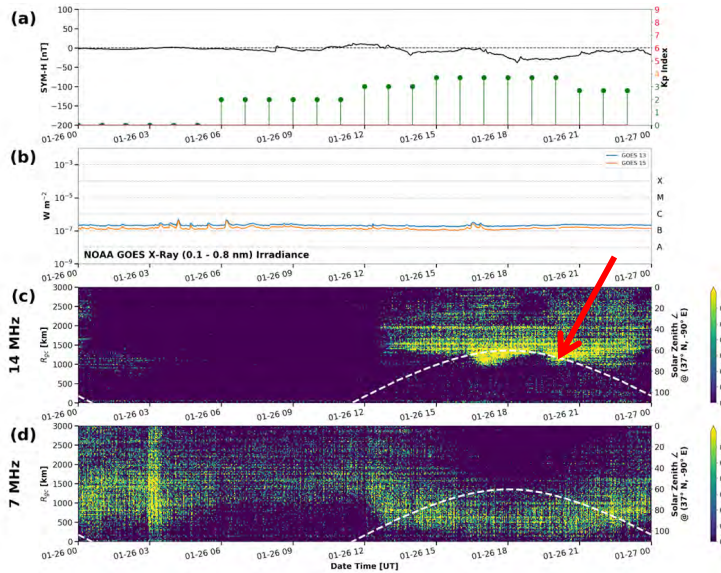
Jan 26, 2017 GNSS TEC Comparison

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27 Jan 2017
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RBN: 48%
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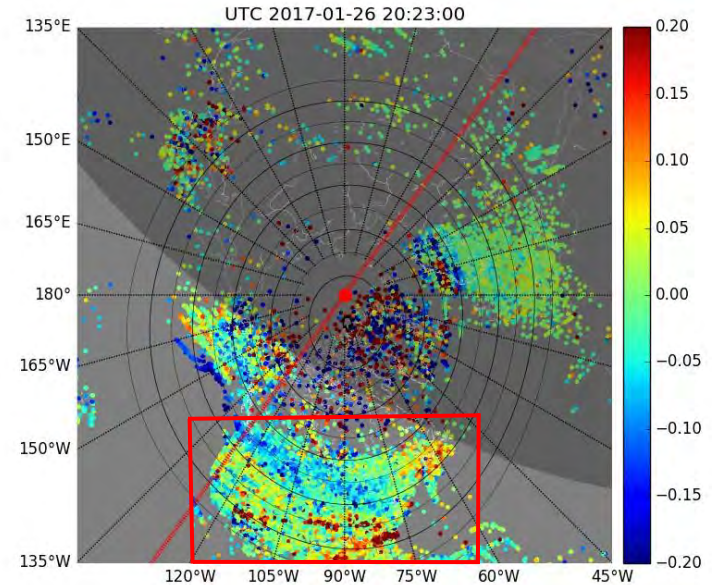
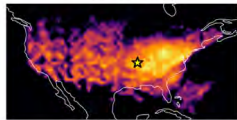
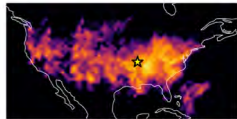
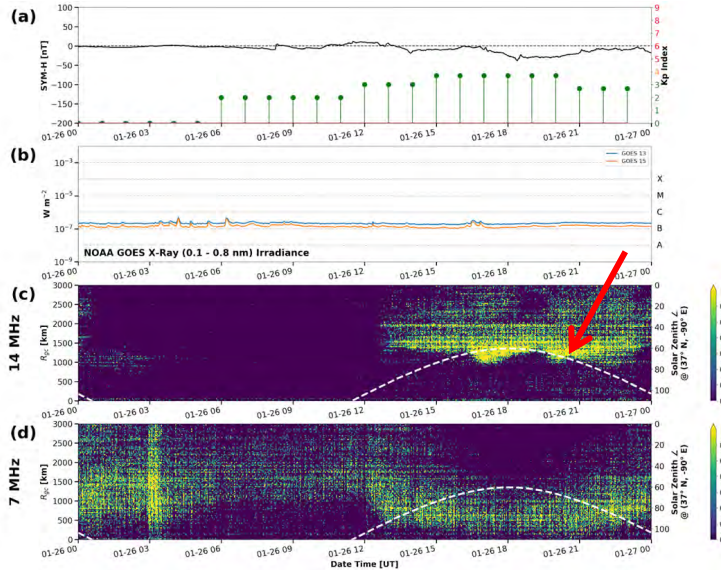
Jan 26, 2017 GNSS TEC Comparison

26 Jan 2017-
27 Jan 2017
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N Spots = 151871
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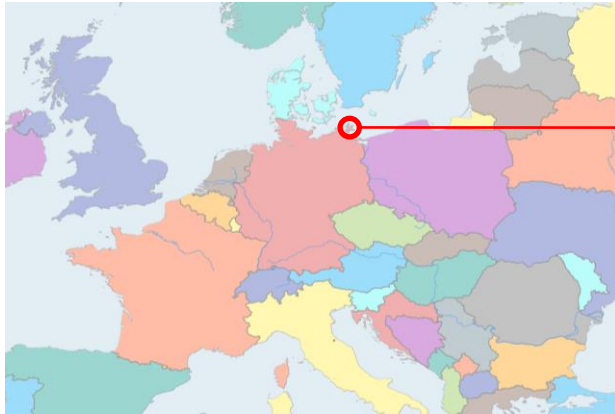


Jan 26, 2017 GNSS TEC Comparison

26 Jan 2017-
27 Jan 2017
Ham Radio Networks
N Spots = 151871
RBN: 48%
WSPRNet: 52%



Ionosonde Data



Juliusruh Ionosonde
Rügen, Germany

- Chose ionosondes relatively close to the largest concentration of radio spots.



Boulder Ionosonde
Colorado, USA

Jan 26, 2017

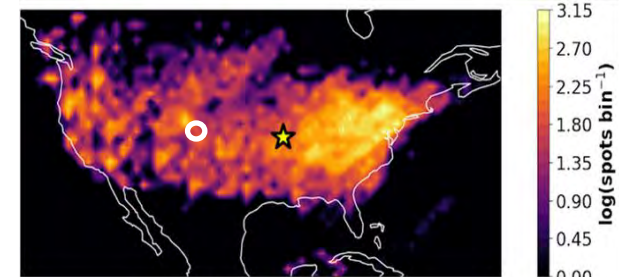
14 MHz



Radio Spots (N = 253931)

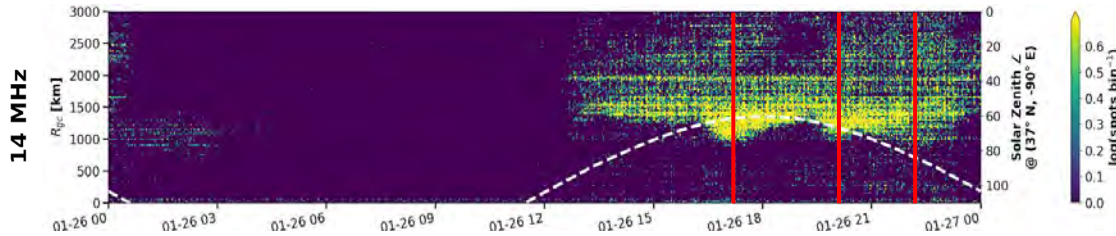
Sep 27, 2017

14 MHz

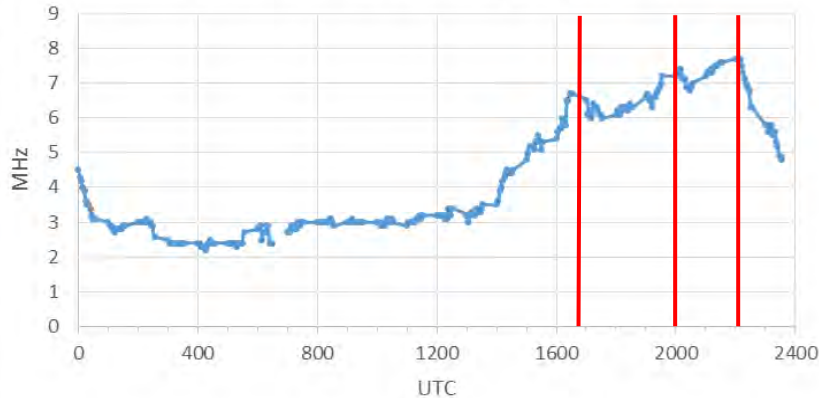


Radio Spots (N = 94417)

January 26, 2017 foF2 Comparison US

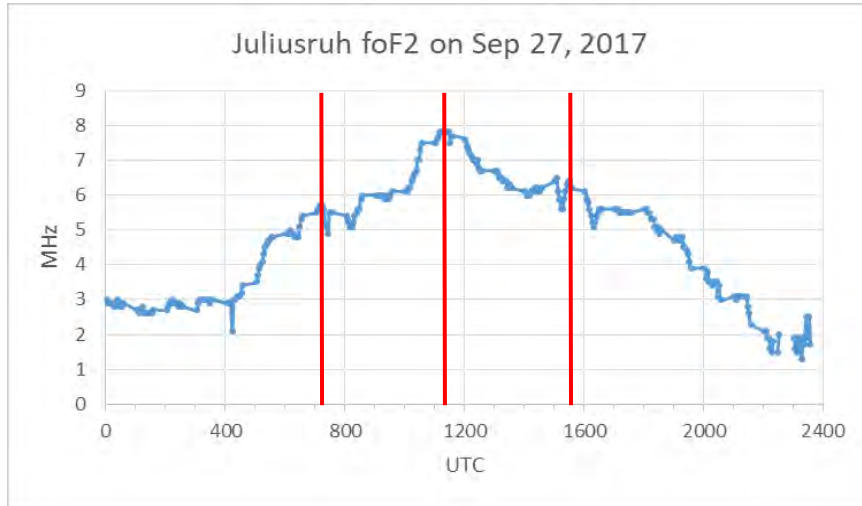
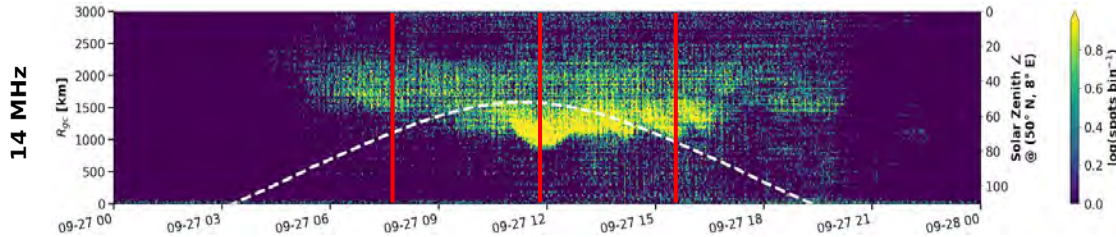


Boulder foF2 on January 26, 2017



- The highest frequency that the ionosonde reflects is called foF2.
- The higher the frequency that is bounced back from the ionosphere, the higher the electron densities will be.
- More refraction at higher electron densities.
- Radio range is shortest at higher foF2 values.

September 27, 2017 foF2 Comparison Europe



- The highest frequency that the ionosonde reflects is called foF2.
- The higher the frequency that is bounced back from the ionosphere, the higher the electron densities will be.
- More refraction at higher electron densities.
- Radio range is shortest at higher foF2 values.

Conclusions and Future Work

- **Ham Radio Disturbances Seem likely to be LSTIDs**
 - Appear coherent across Continental US and Europe
 - Consistent with BKS SuperDARN Beam 13
 - Consistent with GNSS TEC
 - Consistent with Boulder (US) and Juliusruh (Europe) Ionosondes.
- **RBN and WSPR can serve as a tool for monitoring LSTIDs day and night**
- **Find exact source mechanism of the detected LSTIDs.**

References

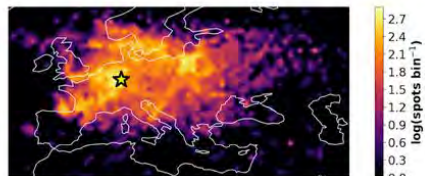
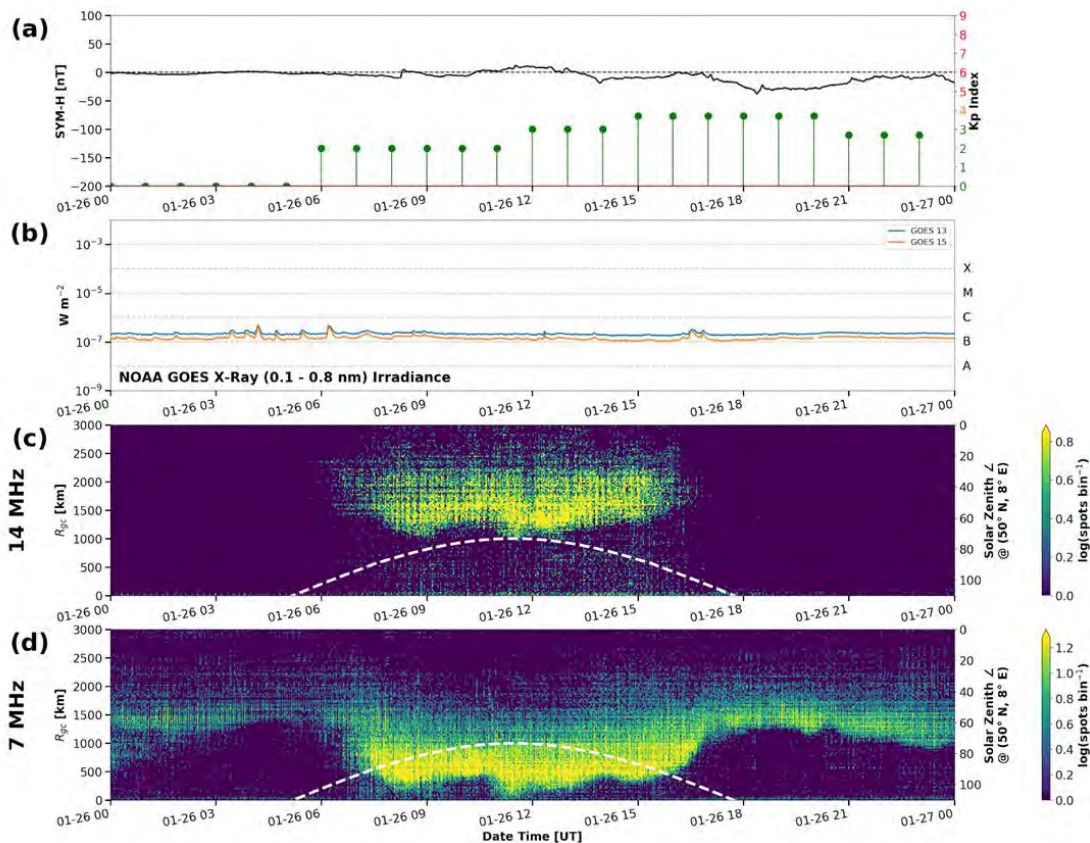
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- Chimonas, G. (1970), The equatorial electrojet as a source of long period traveling ionospheric disturbances, *Planet. Space Sci.*, 18(4), 583–589, doi:10.1016/0032-0633(70)90133-9.
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Extra Slides

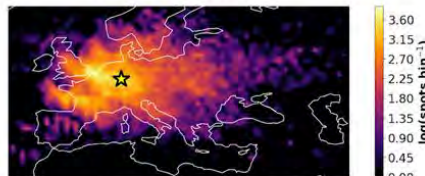


01/26/2017 - 01/27/2017 European Response

26 Jan 2017-
27 Jan 2017
Ham Radio Networks
N Spots = 321853
RBN: 30%
WSPRNet: 70%



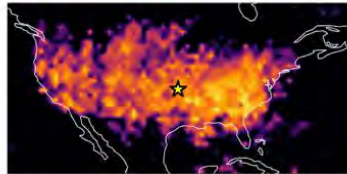
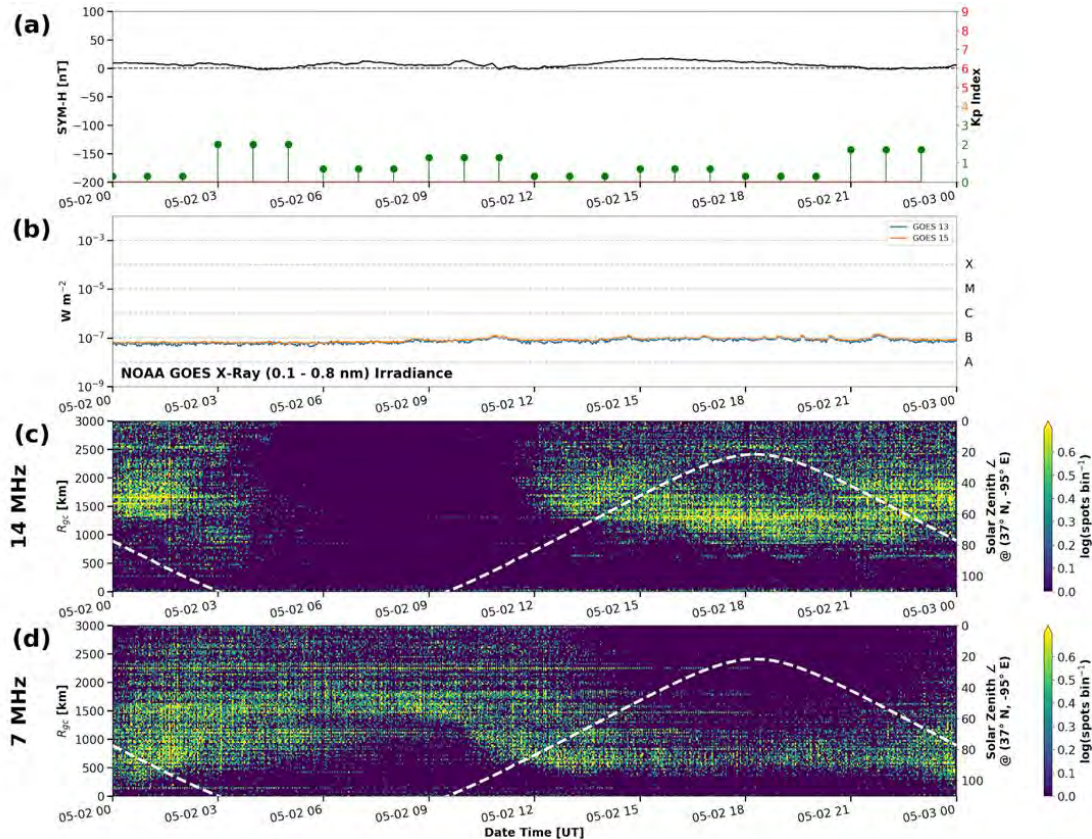
Radio Spots (N = 67922)



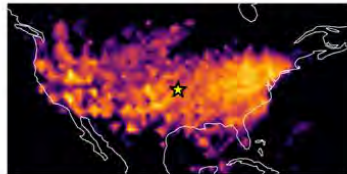
Radio Spots (N = 253931)

05/02/2017 - 05/03/2017 US Response

02 May 2017-
03 May 2017
Ham Radio Networks
N Spots = 161859
RBN: 17%
WSPRNet: 83%



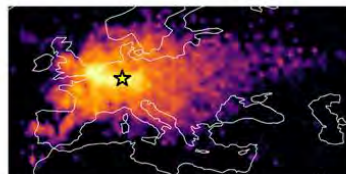
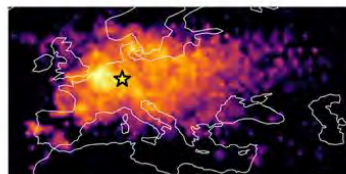
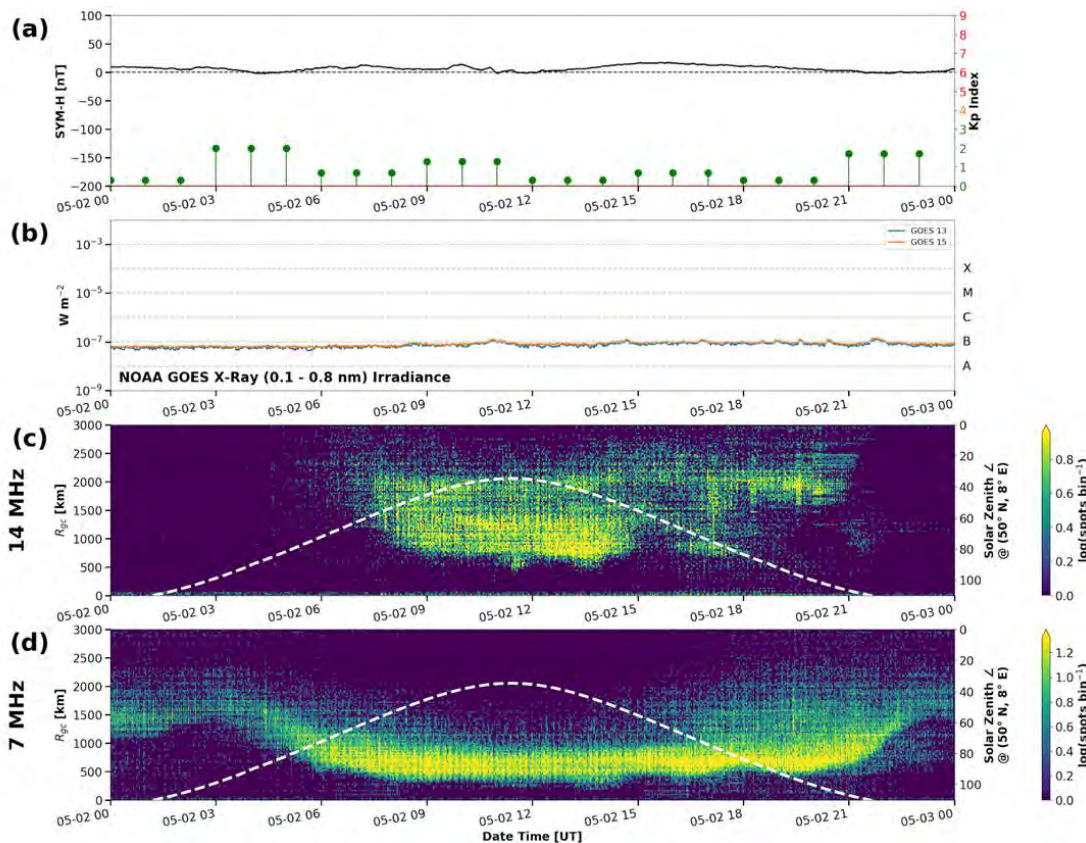
Radio Spots (N = 76748)



Radio Spots (N = 85111)

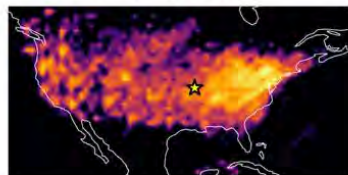
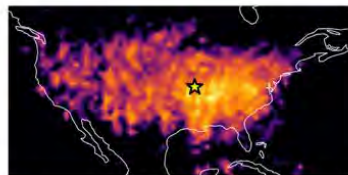
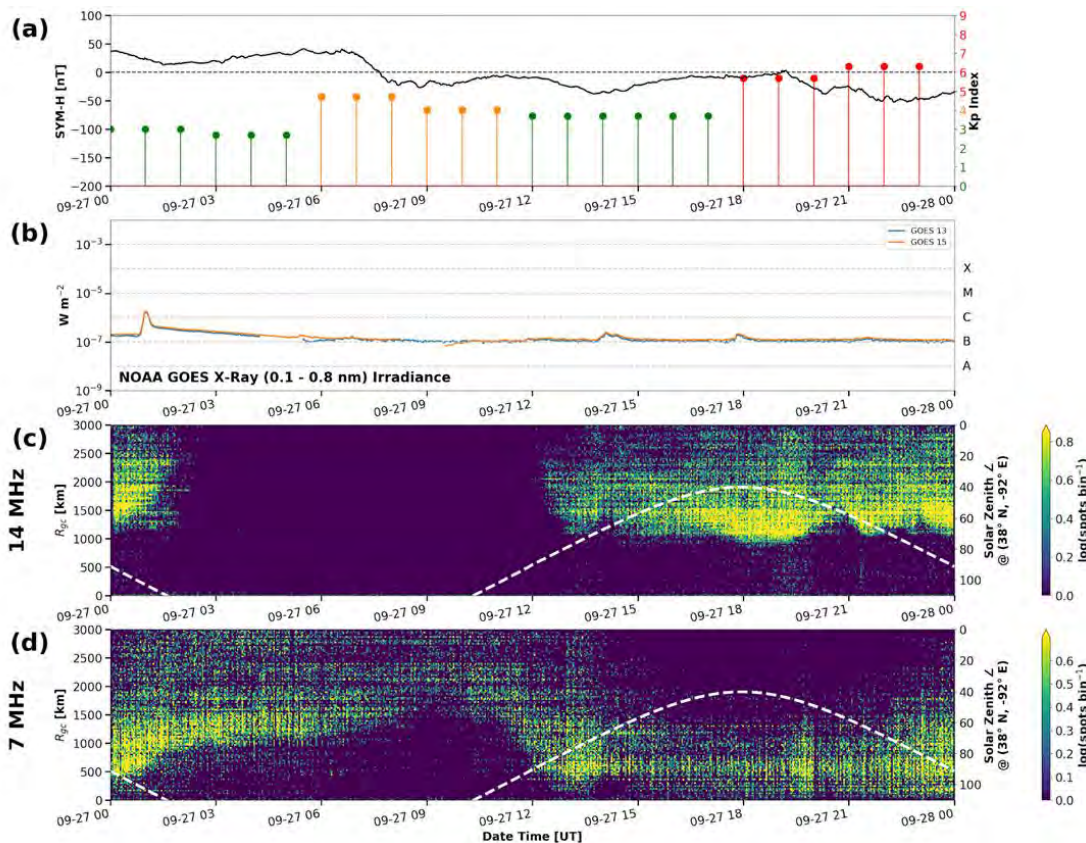
05/02/2017 - 05/03/2017 European Response

02 May 2017-
03 May 2017
Ham Radio Networks
N Spots = 381508
RBN: 16%
WSPRNet: 84%



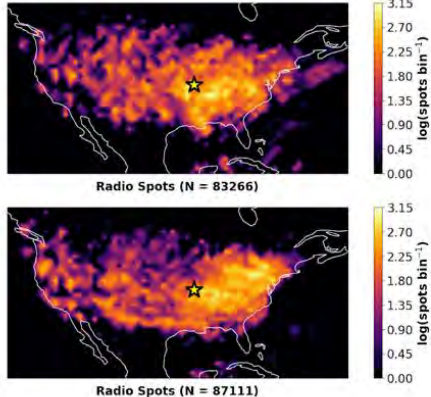
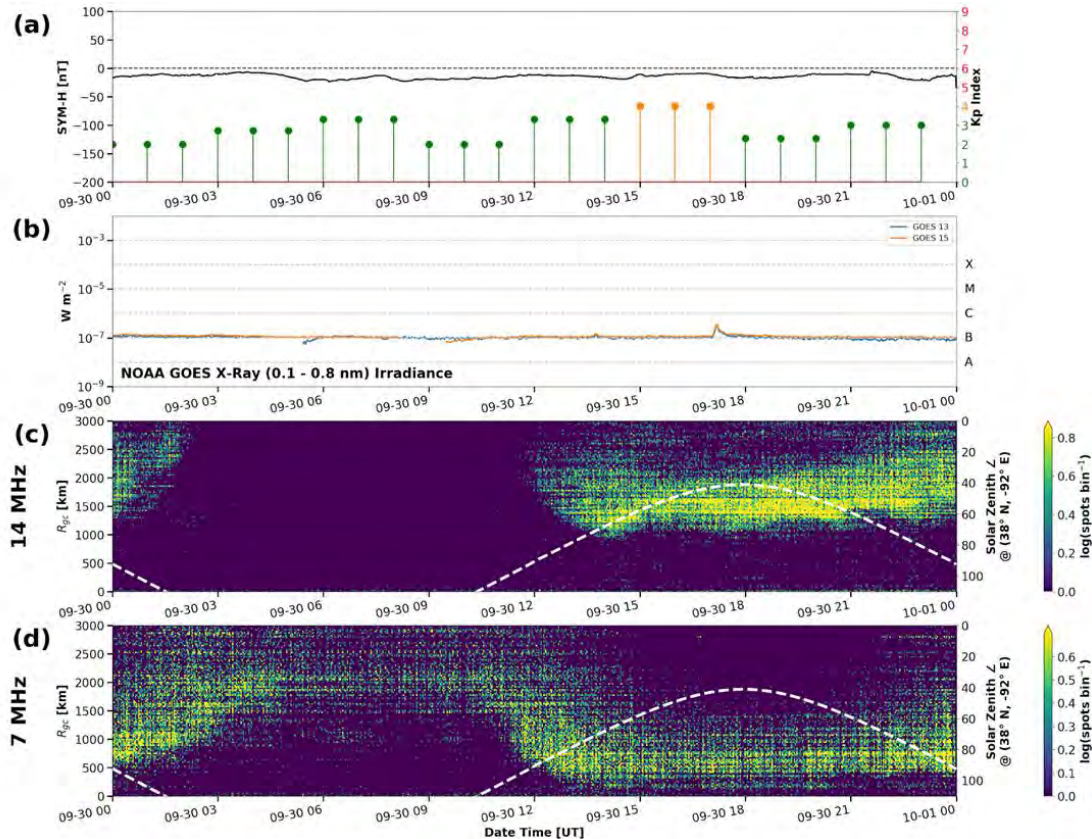
09/27/2017 - 09/28/2017 US Response

27 Sep 2017-
28 Sep 2017
Ham Radio Networks
N Spots = 192946
RBN: 12%
WSPRNet: 88%



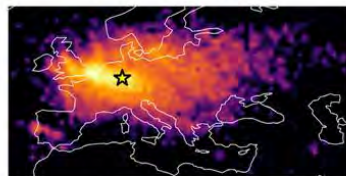
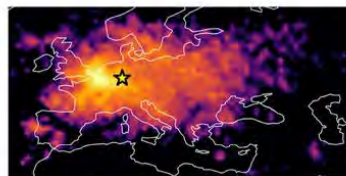
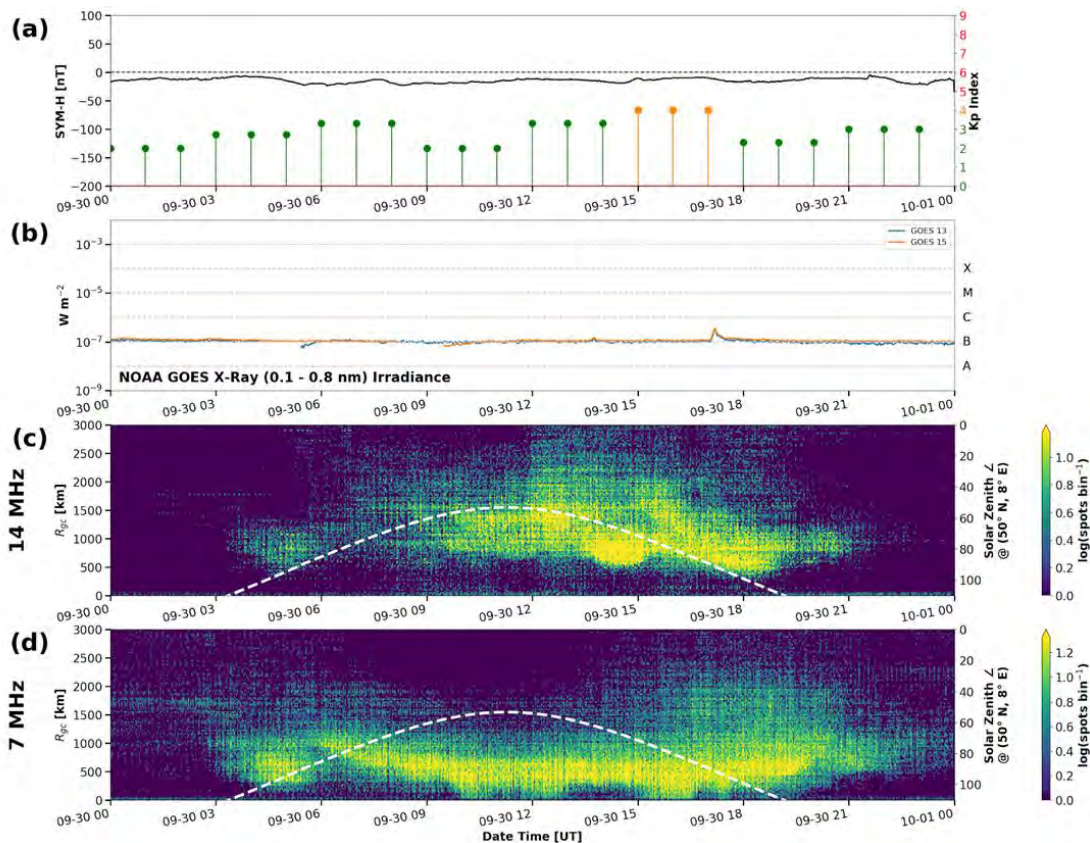
09/30/2017 - 10/01/2017 US Response

30 Sep 2017-
01 Oct 2017
Ham Radio Networks
N Spots = 170377
RBN: 11%
WSPRNet: 89%



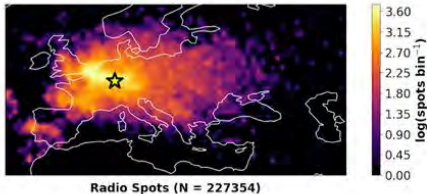
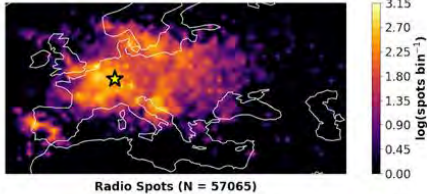
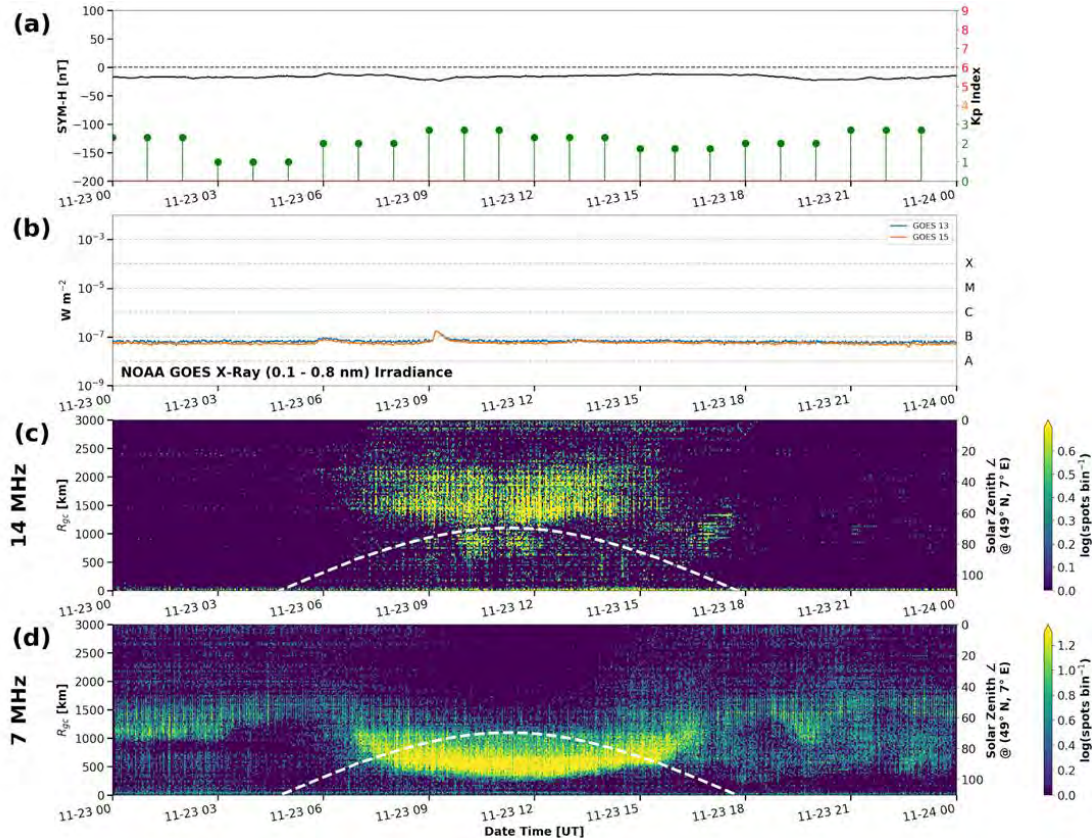
09/30/2017 - 10/01/2017 European Response

30 Sep 2017-
01 Oct 2017
Ham Radio Networks
N Spots = 527440
RBN: 24%
WSPRNet: 76%



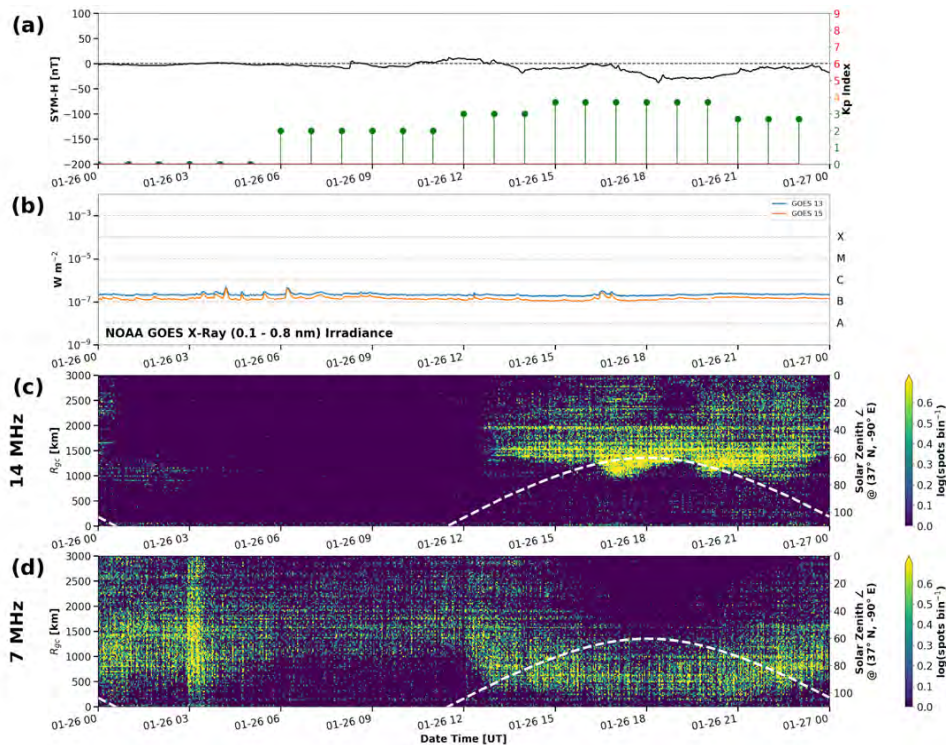
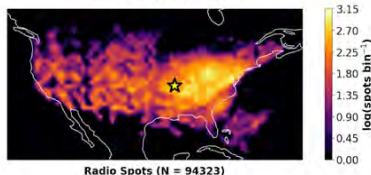
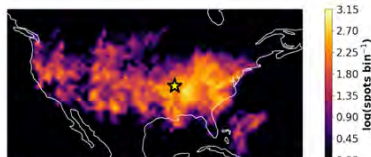
11/23/2017 - 11/24/2017 European Response

23 Nov 2017-
24 Nov 2017
Ham Radio Networks
N Spots = 284419
RBN: 21%
WSPRNet: 79%



01/26/2017 - 01/27/2017 US Response

26 Jan 2017-
27 Jan 2017
Ham Radio Networks
N Spots = 151871
RBN: 48%
WSPRNet: 52%



09/27/2017 - 09/28/2017

European Response

